

COOPERATIVE DEVELOPMENT AND APPLICATION OF A GROUNDWATER MODEL IN SUFFOLK COUNTY, NEW YORK

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ABSTRACT

Suffolk County, New York's 1.3 million residents rely upon groundwater stored in the productive aquifers beneath them as their only source of potable water. Groundwater discharges also provide the baseflows for fresh surface water resources throughout the County, maintaining streams, ponds, and wetland areas. Recognizing the need to wisely manage this irreplaceable resource, regulators and members of the regulated community are working together to understand and manage the resource. An interagency group assembled to develop, calibrate and apply a three-dimensional groundwater flow model of the County. Developing the data base necessary to characterize all of the factors affecting groundwater flow throughout the County could have been a daunting effort. Due to a successful cooperative effort between the Suffolk County Department of Health Services, the Suffolk County Department of Public Works, the Suffolk County Water Authority, the Suffolk County Planning Department, and the New York State Department of Environmental Conservation, however, the model was successfully developed and calibrated in six months.

INTRODUCTION

Suffolk County, an area of approximately 1,424 square kilometers, comprises the eastern two-thirds of Long Island, New York. The County's 1.3 million residents rely upon the groundwater stored in the aquifers beneath them as their only source of potable water supply. As the population of the County has increased dramatically since 1960, stresses on the aquifer system have also increased – the demand for potable water continues to rise, sanitary and other wastes are often discharged to the ground, and in some regions are discharged after treatment to marine waters. These affect the quantity and quality of water recharging the groundwater reservoir.

The Suffolk County Department of Health Services (SCDHS), the Suffolk County Department of Public Works (SCDPW), the Suffolk County Water Authority (SCWA, the largest supplier of potable water in the County), the Suffolk County Planning Department (SCPD) and the New York State Department of Environmental Conservation (NYSDEC) all share responsibility for managing some aspect of the groundwater resource. Together, the SCDHS, SCDPW and SCWA determined that a computer model of the groundwater system on the main body of the island would help them to better understand and manage the impacts that the stresses of increasing development could have on the groundwater resource.

The ultimate product of this project was to be a tool that could be used to evaluate a multitude of questions, issues and problems. To ensure that this tool would be useful to the end users of the model, the project was initiated with a kick-off meeting where all stakeholders articulated their goals and objectives for the project. The myriad of factors affecting groundwater flow within the County were identified and discussed, and the preliminary conceptual model, the framework for the numerical model, and the project schedule were established. Anticipated problems and data gaps were also addressed at the meeting. Perhaps most importantly, the meeting established the open communications and generous sharing of ideas and resources that were key to the project's successful completion.

Throughout the duration of the year-long project, key members of the project team met on a weekly basis to review progress, identify key issues and data requirements, and evaluate results. The weekly sessions also provided hands-on training in the use and application of the model, databases and input/output interface.

On a monthly basis, the project team reported on their progress to the entire group of stakeholders and future model users, who provided feedback, ideas, useful insights and additional data to improve model results. This sharing of ideas and information was essential to maintaining the project schedule.

DEVELOPMENT OF MODEL FRAMEWORK

DYNAMIC groundwater FLOW model (DYNFLOW), a fully three-dimensional finite element computer model was the program selected to model the County, for several reasons, including:

- the finite element approach's flexibility in representing physical characteristics and boundary conditions;
- the powerful and user-friendly companion input-output interface (DYNPLOT) which facilitated input of data from a wide variety of sources, as well as ready evaluation of results; and,
- the program's history of successful application to many areas of Long Island.

Basemaps provided by the SCWA and neighboring Nassau County to the west were used to delineate the study area, shown on figure 1. The model boundaries were established beyond the main body of the County to ensure that all factors that could influence groundwater flow within the County were considered, and to make sure that model results were insensitive to assumed boundary conditions in areas where data was scarce. On the south, the model boundary was extended several miles off-shore, beyond the south shore barrier islands, to allow future consideration of the salt water interfaces in the deeper aquifers. Similarly on the north, the model perimeter was extended north of the coastline into Long Island Sound. To the west, the model reached the Nassau-Queens border, and encompassed all of Nassau County because increased groundwater withdrawals for public water supply and extensive sanitary sewerage were believed to affect groundwater flow in western Suffolk County. To the east, the model was extended out to natural boundaries of the water table aquifer where salt water channels cross the forks.

The 2,519 square kilometers (1,565 square mile) area was then divided into 2,415 nodes defining 4,723 finite elements. To meet project objectives, node spacing was approximately 915 to 1,200 meters (3,000 to 4,000 feet) throughout most of the County. In the southwest part of the County, a highly developed area of particular interest, north-south discretization was increased to approximately 305 meters (1,000 feet) along streambeds and east-west discretization was increased to approximately 710 meters (2,000 feet), to enable accurate representation of groundwater-fed streams.

Vertically, the layers of sand and gravel, silt and clay forming the aquifers and aquitards beneath the County were divided into eight layers, as shown conceptually by figure 2. The relatively impermeable bedrock which underlies the unconsolidated materials of Glacial origin defines the bottom of the model. The bedrock slopes gently to the southeast, and the overlying layers of sands, silts and clays form a wedge that thickens from the north to south, reaching a thickness of over 2,000 feet in the southern part of the County. The major aquifers (in ascending order, the Lloyd aquifer, the Magothy aquifer, and the Upper Glacial aquifer) and aquitards (the Raritan and Gardiner's Clays) have been studied extensively and mapped by the United States Geological Survey (USGS). Their most recent mappings were the basis for the elevations of the top of each unit assigned in the model. These geologic representations were modified by the results of local studies, and the experiences of the geologists in the group. Furthermore, hydrogeologic units with local significance were also represented in the model. The thickest – and most important aquifer from a water supply perspective, the Magothy, was subdivided into several layers, to properly consider the effects of water supply wells screened at different depths. Where additional data was needed to better delineate the thickness, extent or characteristics of a particular unit, the SCWA and the SCDHS provided logs of test borings, and boring logs of monitoring or production wells. Representative horizontal and vertical hydraulic conductivities were assigned to each simulated hydrogeologic unit based upon published estimates, the results of other modeling studies, and pump test results.

Boundary conditions were then assigned to each model node in each model level along the model perimeter, based upon historical mappings of water levels and piezometric heads, or equivalent salt water heads. NYSDEC provided monthly pumping rates for every well field for each water district within the County for each time period simulated. These pumping rates were assigned as specified flux boundary conditions at the model node and model level nearest to the supply well's screened interval. Finally, specified flux boundary conditions were assigned at model level 9, the top level of the model to represent recharge from precipitation, and recharge from wastewater via on-site disposal systems.

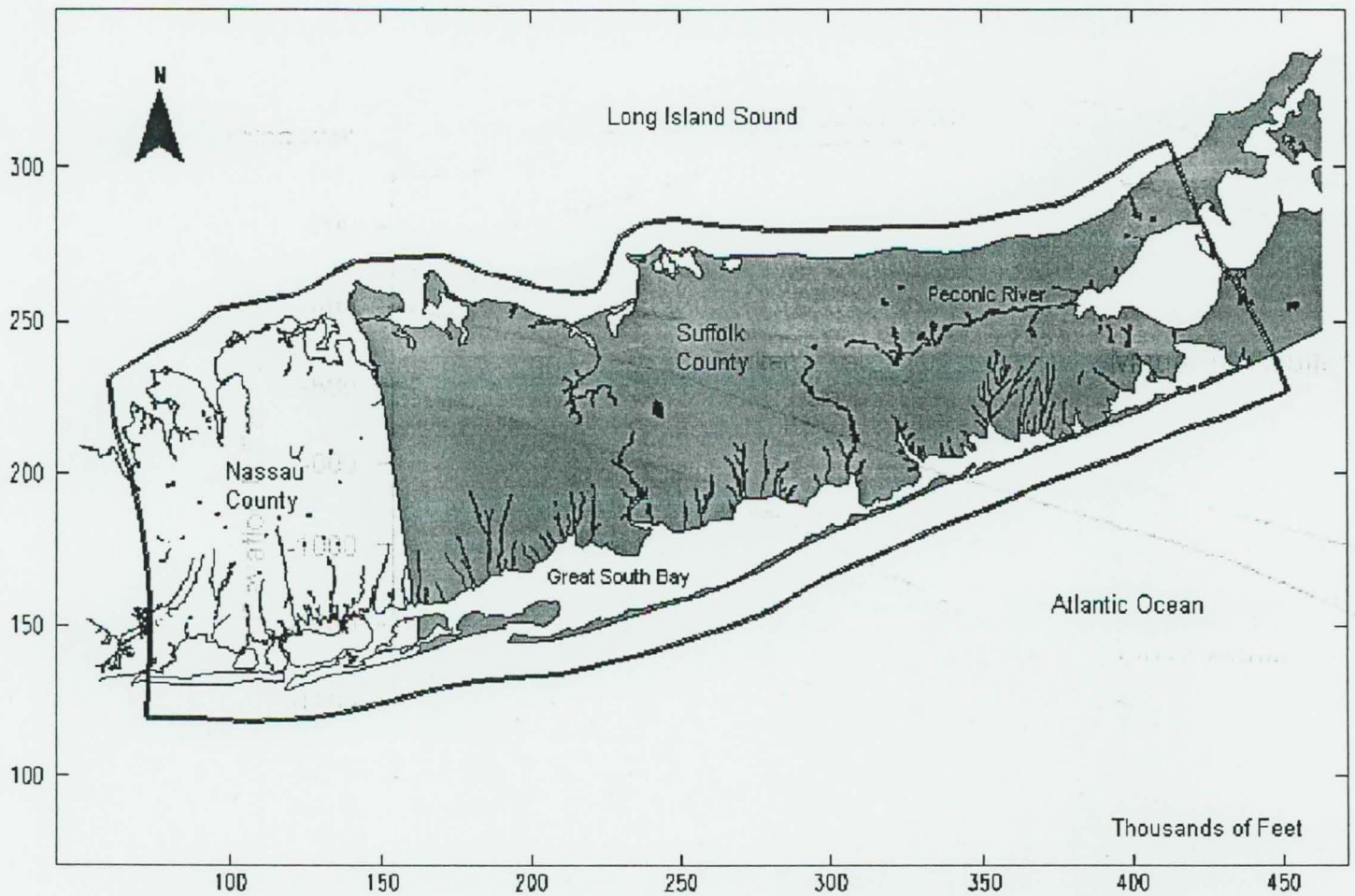


Figure 1. Study Area

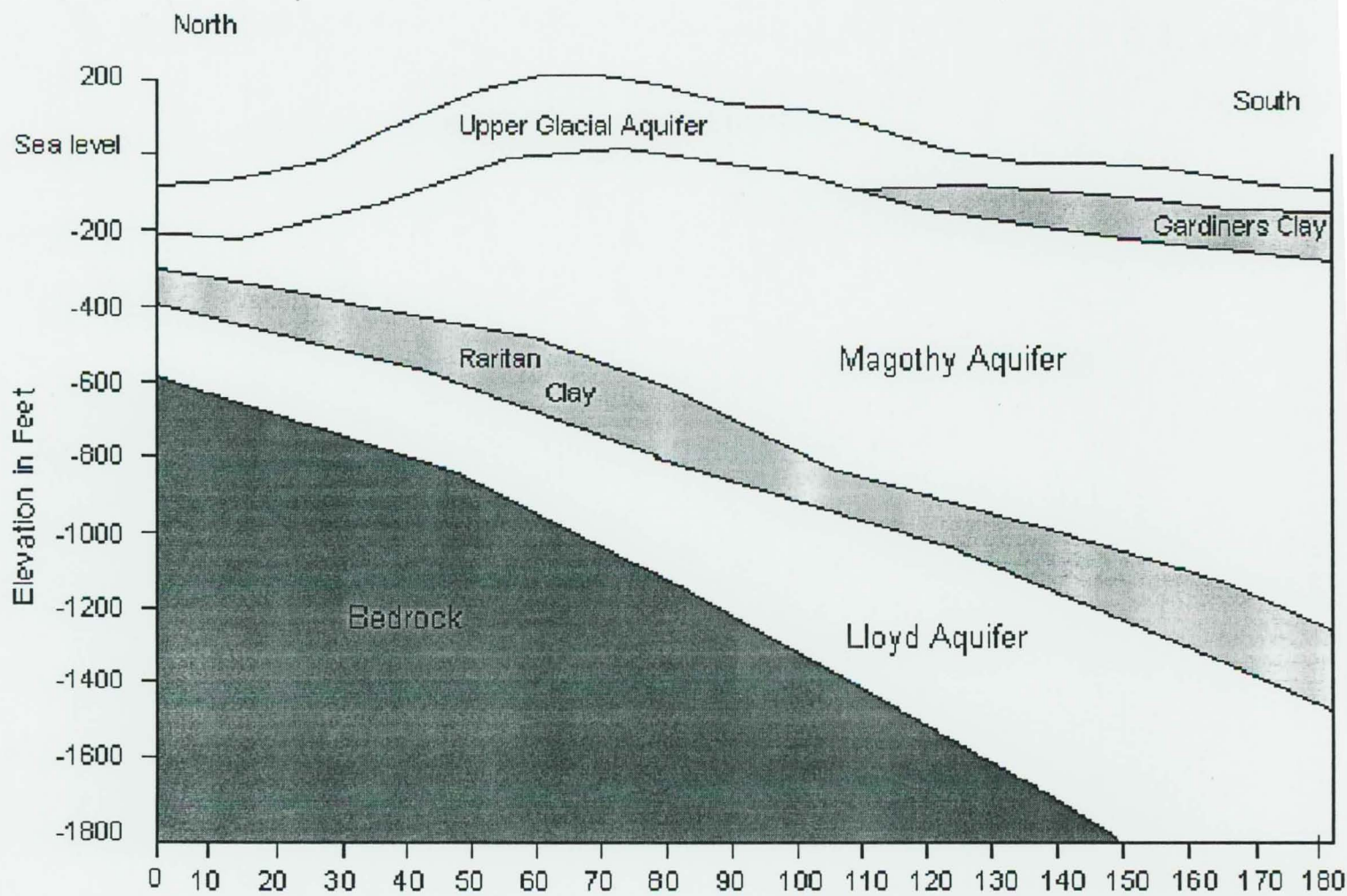


Figure 2. Generalized North-South Cross Section Through Suffolk County

CALIBRATION OF MODEL

The model was calibrated by testing its ability to simulate observed water levels and stream baseflows during two time periods when conditions affecting groundwater flow – that is, precipitation and level of development – were very different. Water levels and stream baseflows measured during early 1994 were selected as the first calibration target. This timeframe represented present-day conditions of development in the County – as defined by water supply pumping rates and locations, stormwater management, and sanitary sewerage – and near average precipitation. The second calibration period selected, 1981, represented a time period of lower than average precipitation, and conditions in southwest Suffolk County prior to the installation of sanitary sewers. The model's ability to represent groundwater flow patterns in the County was further tested by comparison of model results to water levels and stream baseflows measured during 1979, another pre-sewerage period, with higher than average precipitation.

Water levels measured at SCDHS's extensive network of monitoring wells were compared to model-simulated values, until a reasonable match was obtained. While over 500 wells were in the County's database, water level measurements were available for 343 wells during the 1994 time period. The two main calibration parameters that were carefully re-examined and adjusted to improve the model calibration were hydraulic conductivity and recharge rates. Hydraulic conductivity values were adjusted within the ranges established by the literature and previous modeling estimates.

Recharge was considered carefully, as it has been shown that both measured groundwater levels and stream baseflows and simulated groundwater levels and stream baseflows are very sensitive to changes in the rates and locations of recharge. Because precipitation is the sole source of groundwater recharge, precipitation and recharge rates, and the influence of different storm water management practices on stormwater recharge, have been studied extensively on the island.

It has long been reported that for undeveloped conditions, nearly fifty percent of the precipitation falling on Long Island infiltrates down through the unsaturated zone to recharge the aquifer on an annual average basis. Studies conducted at Cornell University have estimated that approximately 85 percent of the precipitation falling during the island's seven month non-growing season (October through April) recharges the aquifer, while nearly all precipitation falling during the five month growing season (May through September) is lost to evapotranspiration. Further studies by the USGS and Nassau County have investigated the impact of stormwater management on recharge rates. Areas where storm sewers convey storm runoff to recharge basins were shown to have a net increase in recharge; areas where storm sewers convey storm runoff directly to streams which discharge to surrounding salt water bodies were shown to have a net decrease in recharge. In general, storm water runoff was conveyed to streams along the south shore and in locales along the northern coast; storm water runoff was conveyed to recharge basins in an inland band stretching from west to east through central Suffolk County, as depicted by figure 3.

SCDHS provided mappings of the thousands of recharge basins located within the County. Recharge from precipitation was then assigned based upon measured precipitation during both the growing and non-growing seasons. Recharge rates varied across the County, depending upon whether the land area was undeveloped, or whether storm water runoff was discharged to recharge basins or to streams.

Before extensive development, groundwater withdrawn from the aquifer system was returned to the ground via on-site septic systems; essentially all of the water withdrawn from the aquifer was returned. As the County's population increased, impacts on groundwater quality were observed from on-site wastewater disposal systems in densely populated areas. Collection, treatment and off-shore disposal of the wastewater was one method selected to protect groundwater quality. Off-shore discharge of the water represented a net loss from the groundwater system, this loss was also considered by the model. SCDPW provided mappings of sewer districts within the County that discharged to surrounding coastal waters (figure 4), as well as locations of those sewer districts that discharged treated wastewater back to the ground. Approximately 85 percent of the groundwater withdrawn in areas served by sewer districts that discharge treated wastewater back to the ground, and in areas where on-site septic systems are used for disposal of sanitary wastewater, was returned to the aquifer as a specified flux boundary.

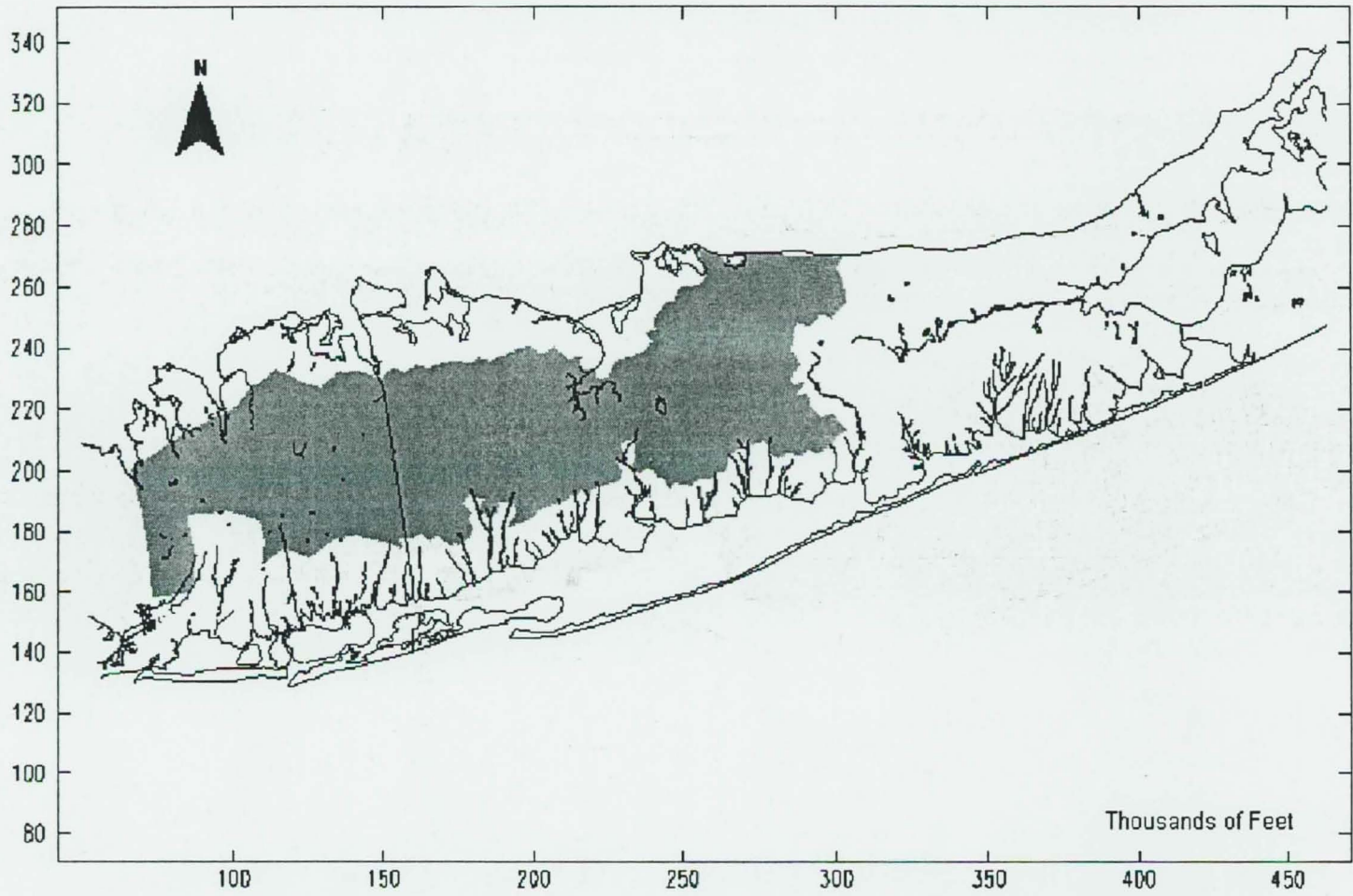


Figure 3. Area where Stormwater Runoff Discharges to Recharge Basins

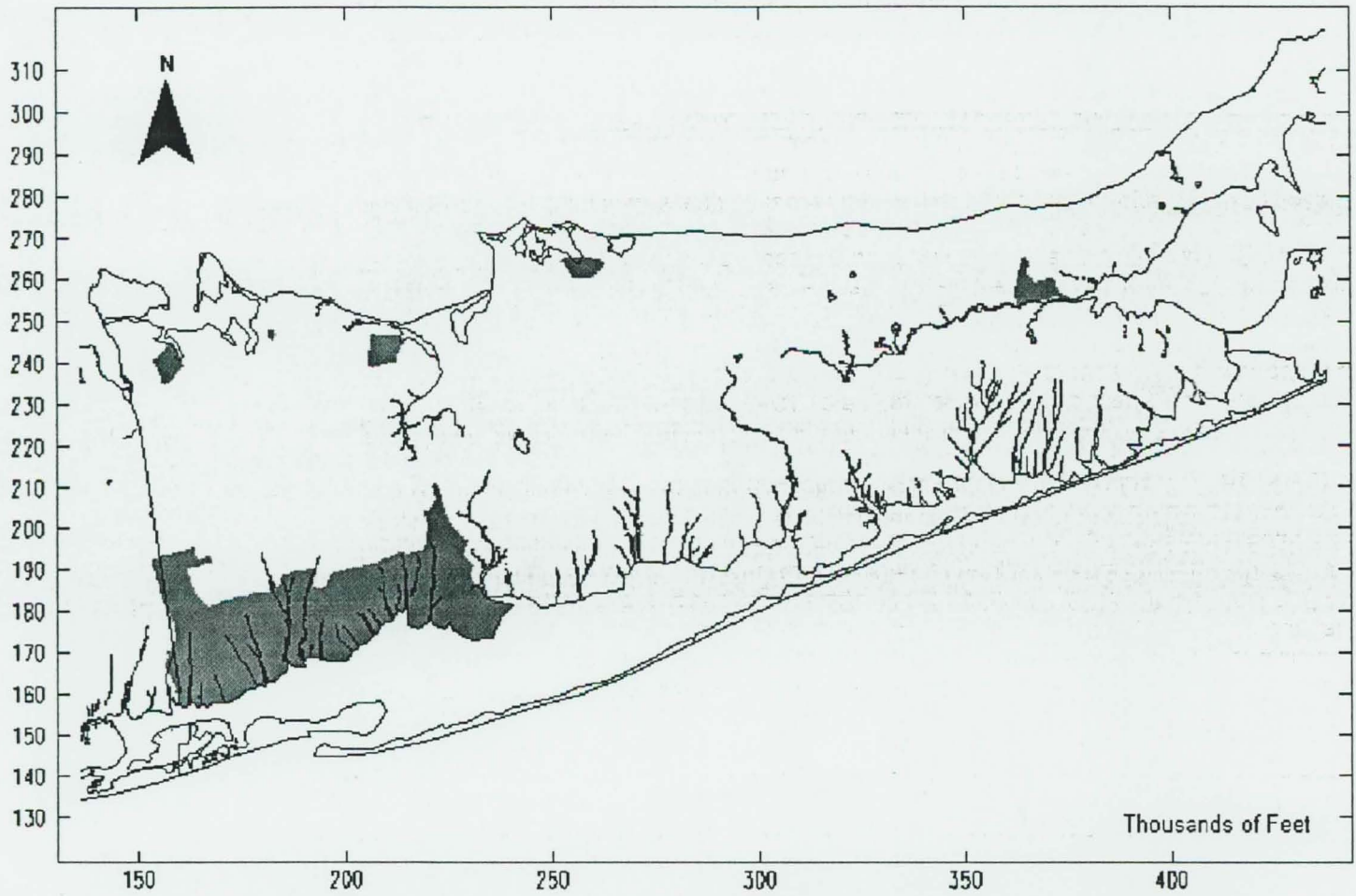


Figure 4. Sanitary Sewer Districts Discharging to Coastal Waters

After thoughtful examination and adjustment of calibration parameters, the model was able to closely match observed water levels throughout the County within all aquifers during the time periods considered. Table 1 summarizes the comparison of measured and model-simulated water levels for the calibration periods.

Finally, conditions within the highly developed southwest part of the County were further tested by a transient simulation of water levels and stream baseflows from 1981 through 1995. The model's success in representing stream baseflows in the largest stream in eastern Suffolk County, the Peconic River, is shown by figure 5.

After the model was calibrated, it could be used with some confidence to predict the groundwater system's response to changes in natural and man-made stresses.

MODEL APPLICATIONS

As Suffolk County developed, groundwater was withdrawn from the aquifer for potable supply, and then discharged to on-site septic systems, which returned the water – now containing various contaminants such as nitrates and organics – down to the aquifer. In the more densely developed areas of the County, the concentrations of contaminants associated with human waste increased and threatened to compromise the water supply. When the County planned to collect, treat and dispose of the treated sanitary wastewater off-shore to protect groundwater quality, it also recognized that removing the water from the aquifer system represented a net loss. When the County's largest sewer district, the 30 million gallon per day (MGD) Southwest Sewer District (SWSD) was constructed in the early 1980s, it was hypothesized that removal of this water from the aquifer system would cause a significant reduction of the local water table. It was further predicted that this lowered water table would significantly reduce groundwater contributions to local fresh water features, and would result in reduced stream baseflows, lower pond levels, and the drying up of stream headwaters and area wetlands.

Together with the U.S. Environmental Protection Agency (EPA) and NYSDEC, SCDHS and SCDPW studied the freshwater resources in the southwest part of the County extensively from 1980 through the present, documenting their work in a series of Flow Augmentation Needs Study (FANS) reports, and developing mitigation plans. An early groundwater model predicted significant reductions in stream baseflows and pond levels, resulting from sanitary sewerage in Nassau and Suffolk Counties, given a set of assumed future average steady-state conditions. When a long-term monitoring program could not confirm that the predicted declines had taken place, it was unclear whether or not mitigation of the area's fresh water resources was warranted. The first application of the Suffolk County groundwater model was to evaluate the impact that the County's sewerage program had on area streams and ponds. Because the model was able to incorporate actual variations in precipitation, water supply pumping locations and rates, and incremental flows to the wastewater treatment facility, it provided a more realistic assessment than previous models of sanitary sewerage impacts upon groundwater levels and stream baseflows. The model results indicated that actual impacts on local streams were not as severe as originally predicted, because actual flows to the wastewater treatment plant never reached the maximum predicted flows, and because shallow public supply wells were replaced by deeper wells outside of the stream corridors.

Working together, the group then used the calibrated flow model to predict the effects of sustained low precipitation on streams throughout the County. Seasonal reductions in baseflow, and reduced lengths of flowing stream were predicted. The group has also used the County-wide model as the basis for more detailed local models. One sub-regional flow model was developed to evaluate the impacts of nitrate discharges from a small wastewater treatment plant on downgradient groundwater quality, the second, to simulate the migration of a plume of dissolved contaminants resulting from historical operations at a local industrial site.

FUTURE APPLICATIONS

Suffolk County has anticipated using the flow model to help to respond to a wide variety of water resource management and water supply protection issues. The flow model of the main body of the

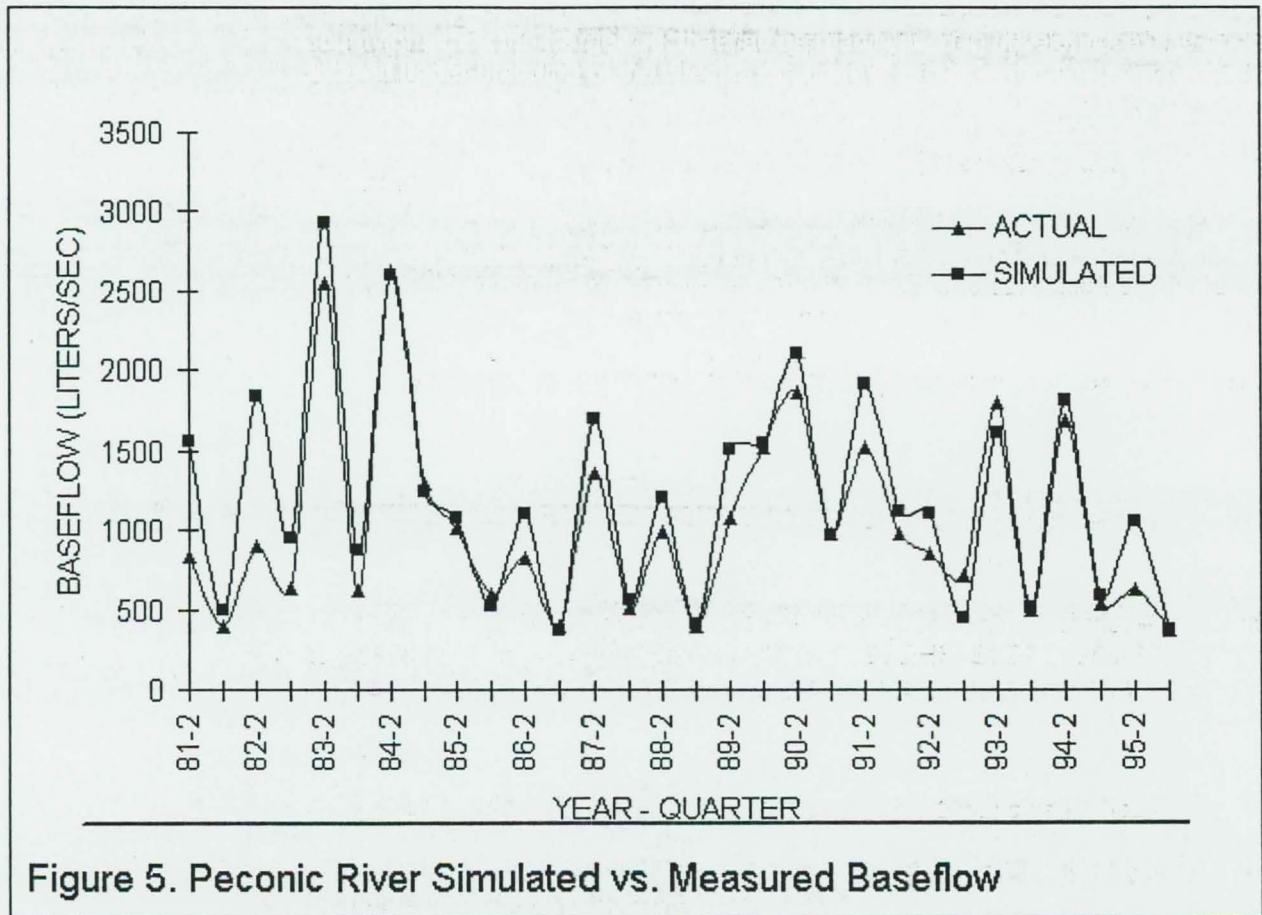


Figure 5. Peconic River Simulated vs. Measured Baseflow

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County provides the framework that can be readily used to develop local site-specific models when more detailed understanding of the direction and rate of groundwater flow is important. In addition, the flow model can be coupled with contaminant transport and salt water interface codes to study contaminant migration, the potential for movement of the salt water interfaces or salt water upconing resulting from changes in water supply pumping locations or rates. Examples of applications that the County plans for the coming year include:

- delineation of groundwater contributing areas for critical surface water habitats located within embayments on the north and south shores, and estimation of nitrogen loadings to these surface waters from groundwater discharges;
- simulation of the migration of dissolved contaminant plumes from hazardous waste sites;
- evaluation of the effectiveness of existing monitoring wells in identifying contamination migrating from hazardous waste sites before it threatens water supply wells; and,
- estimation of salt water interface migration and salt water upconing potential within a coastal community facing increased development pressure.

Most significantly, the County's groundwater model is truly just that – today, the model may be accessed by Suffolk County representatives on SCDHS, SCDPW and SCWA personal computers, to understand and respond to groundwater management issues as they arise.

REFERENCES

Camp Dresser & McKee (1990), *Nassau County Groundwater Model*

Ku, J.F., N.W. Hagelin and H.T. Buxton, "Effects of Urban Storm-Runoff Control on Groundwater Recharge in Nassau County, New York" USGS.

Smolensky, D.A., J.T. Buxton and P.K. Shernoff, (1989) "Hydrologic Framework of Long Island, New York," USGS Hydrologic Investigations Atlas, HA-709

Steenhuis, Tammo S., Craig D. Jackson, Samuel K.J. Kung, Wilfred Brutseart "Measurement of Groundwater Recharge on Eastern Long Island." *Journal of Hydrology*.